<u>Soil Nitrifiers: Who They Are and What They Do</u>

Mentors: Di Liang (PhD Candidate) & Dr. Phil Robertson (KBS-MSU Faculty)

Soil nitrification is the process that converts ammonia (NH_3) to nitrite (NO_2^-) and nitrate (NO_3^-). For over a century, ammonia oxidizing bacteria (AOB) were thought to be the only taxa involved in this process. The recent discovery of *Nitrosopumilus maritimus* (SCM1) confirmed ammonia oxidizing archaea (AOA) as another major participant. AOA are mainly found in low-ammonia and acidic environments while AOB prefer high nutrients and circumneutral conditions. Despite the genetic similarities between AOA and AOB, little is known regarding the unique evolution and adaptation of AOA to low-nutrient conditions.

One phenomenon that has confused scientists for many years is the ubiquity and abundance of AOA in almost all terrestrial ecosystems. Using ammonia monooxygenase subunit A (amoA) as a functional marker, studies have shown that AOA can be up to 3000 time more abundant than AOB in soils. As previously noted, AOA thrived mainly in low nutrient environments. If so, then the question is: how could AOA outnumber AOB if there are not enough nutrients available?

Researchers are looking at this question from two aspects: carbon and nitrogen. Carbon and nitrogen are basic building blocks for every organism. Both AOA and AOB gain energy by oxidizing NH_3, and previous studies demonstrated that AOA grew exponentially with NH_3 as low as 10 nM, which is 100 times lower than the NH_3 required by AOB. It is not hard, therefore, to imagine how competitive AOA could be in a resource limiting world where AOB begin to starve. Another factor that distinguishes AOA from AOB is the carbon source. Genomic studies reveal that AOB adopt the Calvin–Bassham–Benson (CBB) cycle and fix CO_2 with the RubisCO enzyme. Lacking the genes encoding RubisCO, AOA participate in the HP/HB CO_2 fixation pathway. AOA also possess the genes encoding enzymes for all the steps of tricarboxylic acid (TCA) cycle. What is the difference between the CBB and HP/HB cycle? First, CBB uses CO_2 as the carbon source while HP/HB assimilates bicarbonate (HCO_3^-) as the carbon source. Second, compared to the costly CBB cycle, the HP/HB cycle adopted by AOA saves one third of the required ATP. In short, high NH_3 affinity and efficient carbon fixation pathway help AOA to dominate.

The aforementioned knowledge is mostly gained from pure culture research. Field studies focusing on understanding the metabolisms of AOA and AOB are rare. Soil environments, differing in vegetation types, land management intensities, soil organic matter, and soil pH, could have profound effects on physiologies and adaptations of AOA and AOB. Much is unclear and remains to be explored for this research topic. Thus, this URA project seeks to investigate how AOA and AOB use carbon and nitrogen sources in different ecosystems. The student will learn experimental design, data analysis and interdisciplinary skills in microbial ecology. Feel free to drop an email to Di Liang (liangdi@msu.edu) for questions!